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An Inaugural Essay

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very good –

Circulation of the Blood.

Submitted to the Medical Faculty, Provost, &c.

of the University of Pennsylvania,

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by

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of

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There are few subjects in Physiology, less understood than the circulation of the blood; from the intricacy of its movement through the capillary and venous systems, it seems to have eluded the researches of science, and most of the theories formed on it, and disseminated in the schools, are based more upon conjecture than observation: hence it becomes a proper subject for examination, how far these different views are founded on reason and fact, and to what extent we may select matter from the various conflicting opinions to arrive at the truth.—

Bichat being the most prominent amongst those who have enriched Medical science in this, or any other age, I shall freely draw from his invaluable stores, as the best repository of knowledge; indeed it is my intention to do little more than follow in the path already beaten by this great luminary, and by canvassing whatever starts up, that may appear not clearly elucidated, I can at least hope to become acquainted with his principles and inestimable facts; it is not the province of a

student, to seize boldly on the helm of discovery, and steer through the quicksands of error, or amid the dark delusions that attend even the most skilful: this belongs undoubtedly to the practised mind of the physician: it requires knowledge, ample experience, and the nicest tact; the perseverance of a Morgagni, or the genius of a Hunter. But, by examining, with due deference their theories, to acquire a habit of thinking boldly, of concluding correctly, and deciding justly, is certainly within the limits of his capacity, and his imperative duty. — Impressed with these views, I have rejected the dubious chance, of experimenting with an unskilful eye, and deficient apparatus, for the less brilliant prospect, of following an author through his own discoveries, and offering my feeble comments upon them.

The circulation of the blood, since the time of its discoverer, Harvey, has engaged the close study of every physiologist: and with so much labour already bestowed upon it, with so little success, may be supposed to possess no little intricacy. Notwithstanding the streams of talent

which have flowed upon it in modern times, the most important and vital phenomena of its movement, remain yet undiscovered. The mysterious return of its columns to the heart, the offices which it apparently performs of, nutrition, exhalation, and absorption, and the deeply hidden objects of the abdominal circulation, are explained only on conjectural hypotheses and contradictory theories. It is reserved for a future Hunter or Bichat, to elucidate these knotty subjects, and perhaps effect a great and final revolution in our science: until then we must be content to speculate, with our, yet imperfect and broken chain of explanations.

The circulation is divided by Bichat into two kinds: viz. that of the red and black blood, the limits of each, being the pulmonary and general capillaries: the first or that of the red blood, commences in the extreme vessels, ramifying on the air cells of the lungs, which collecting into branches, and these again into trunks, it is discharged by four veins into the left auricle of the heart; thence it passes into the left ventricle and is distributed by its contraction through the aorta and

its branches, to the general capillaries; the route in this circulation of the blood, resembles radii proceeding from the superficies to the centre, and thence to an opposite and similar surface, or in other words, it forms two cones, joined together at their apices; at this place of junction, is situated the efficient organ of all its movements, the heart; this, being possessed of an apparatus for propelling the contained column, by its contraction forces the blood into the arteries, and through them, to the capillaries: it is supposed also, by many to facilitate the return of the pulmonary blood by its dilatation.—

This movement, however, simple as it may at first appear, is the subject of many theories, opposite in character, and of high pretensions.— Harvey, and the mechanicians, referred it altogether to the heart, and consequently considered the arteries as passive tubes: Hunter, and most modern writers give these latter the attributes of muscularity, and make them serve materially in the motion of the blood, whilst Bichat, depriving them of muscular structure, considers their contraction only the effect of texture, and gives them a middle station. Unprepared

as I am with facts, I can only view through a hazy atmosphere the field of contest. — The heart, being of a muscular nature, certainly contracts, with great force, and of itself would suffice to throw the column into the capillary system, as is proved by the great power it exerts when cut from a frog, and placed upon the finger; moreover, the relative magnitudes of its right and left ventricles, so exactly corresponding with their offices shew, that whatever influence the arteries may have, it is the great cause of the circulation. — Every theorist has admitted that this organ, gives the greatest impetus to the blood in those animals that possess it; though at the same time we know many to be destitute of it in whom the motion of the blood must depend on the capillary circulation, and the muscular fibres demonstrated to exist in those arteries. —

Admitting this to be the fact, our next object is, to know what agency the arteries have in continuing the momentum imparted by the heart. — As regards their construction, anatomists differ: Hunter describes them as tubes with 3 coats, viz:— an external or cellular, an internal or nervous, and

a middle, which he considers, elastic and muscular, the latter or muscular being within the former. The fibres of this muscular coat, he supposes to operate, in the systole, or contraction of an artery: to determine how far this structure coincided, with the muscular texture elsewhere, he bled a horse to death, and found that by stretching transversly, sections of different arteries, they did not return to their original dimensions: hence appeared a similarity to the muscles of the body, which when stretched after death, do not resume their original dimentions: a muscle, once stretched after death, does not shorten at all; but according to his results the artery contracted to nearly its original diameter: a perfectly elastic body loses nothing of its shape by extension, and hence he arrived at the conclusion, that the contraction was due to the external lamina of the middle coat, and its want of perfect elasticity to the internal or muscular: he also observed that in a section of the aorta, the elastic projected beyond the muscular lamina. — Bichat, in his account of the middle tunic of the arteries, describes it as a peculiar texture

ture, partaking of the fibrous & elastic, though belonging to neither. It is composed, according to him, of circular fibres, which are capable of distension to a certain extent, but beyond this, are ruptured: to this he refers the contraction of the arteries, not from muscular motion, but simply, the contractility of texture; How far these opposite views, may be owing to imperfect observation on either side, I am incompetent to say: but that the alledged muscularity of the arteries, is in some measure overrated, I think may be well worth attempting to prove. The experiments of Mr. Hunter certainly shew, what must be the fact, that the arteries are not perfectly elastic; but do they prove also that the muscular fibre is present? Even he himself acknowledges that he "never could discover the direction of the muscular fibres." According to Dr: Jackson all the experiments of Berzelius and modern chemists have not been able to detect fibrin in this texture: Besides, if the arteries possess muscularity, they should sustain comparatively the same weight, that any other known muscular structure will, in life and death. This however

is not the case, as is shewn by the following quotation from Bichat. "If we draw in a contrary direction, the two ends of an artery and a muscle, we effect with more difficulty the rupture of the first, when the dead body, is the subject of this comparative experiment: but upon the living the effect is opposite: the vessel yields to a very strong action made upon it: it would be necessary that this action should be incomparably greater to divide the muscle." The first experiment of Hunter was with a circular section of the aorta, which, measuring 5½ inches was stretched to 10½ inches: the force being withdrawn, it contracted to 6 inches: nearly its original dimensions.- Why may not this be owing to an imperfectly elastic membrane, such as Bichat describes? If there be that great disparity of strength between the dead & living muscle, certainly, the arterial structure, which according to those who think it muscular, must be sufficiently so to propel a heavy column of blood, should exhibit a vast difference in the two states: but, from the above quotation, there would seem to be, nearly an equal

power in both. On the other hand, the experiments tried by Mr. Hunter, which consisted in making sections of the aorta, may readily appear conclusive. When at the minimum state of contraction, he cut an artery, the elastic coat projected beyond the other; but when the artery was stretched transversely and then cut, the muscular coat projected.

The succeeding experiments of a similar nature, were performed on the iliac and axillary arteries: from these he inferred, that, as there was less elasticity, in the latter, than the aorta, the muscular structure must predominate, as the arteries receded from the heart: Again he observes that, "in animals, whose arteries, are very muscular, the heart is proportionably weaker, so that the muscular power of the vessels, becomes a second part to the heart, acting where the power of the heart, begins to fail, and increasing in strength, as that increases in power". This last paragraph would seem to bear down all oppositions; yet we have only to consult the first page of Bichat, on this membrane, to find the following: "The thickness of the peculiar membrane of the arteries, is very evident in the great

trunks: it constantly diminishes: a circumstance that distinguishes it essentially from the internal membrane, which I have found almost as thick in the tibial artery as in the aorta". Bichat observes, that "the muscular texture is soft, loose, and very extensible: the arterial texture, on the contrary, is firm and solid, breaking before it yields." In addition to this he has endeavoured to show, that in almost every point of view, there is a real difference in the nature of the two substances, perhaps only excepting the fibrous appearance, presented by both: these fibres he asserts to be circular. —

From the best data, that I can collect, amid the diversity of opinion, it appears to me, most probable, that the arteries are a series of tubes, composed of 3 membranes, the first, or condensed cellular tunic, imparting strength, and elasticity to the structure, and at the same time, resisting those substances which are calculated to rupture or break it, as ligatures, aneurisms &c. serving also as a smooth, and lubricated envelope for the performance of its movements, in extension and locomotion, and, as an elastic protection, when violently put upon the stretch.

The second, or peculiar coat of Bichat, is a membrane, essentially different in its properties from the other membranes of the body, serving by its circular fibres, if they be of a fibrous character, to strengthen greatly the parietes of those tubes, against lateral pressure, and engorgement, and admitting of distention, only to the limit of those fibres. The third, or internal coat is thin, and furnishes a smooth and lubricated surface for the passage of the blood.— According to Bichat, this is the seat of ossifications, but the majority of anatomists consider this affections, as located in the middle coat.— Unitedly, they compose a set of cylindrical vessels, capable of distension, only to a certain point, beyond which the two internal coats must rupture;—

Hence, we arrive at the conclusion, that the heart by its contraction, throws the blood into the aorta, which is guarded by the semilunar valves.— Now the mechanism of this operation, I conceive to be this: considering the blood, as a liquid almost inelastic, it must follow, that when, by its force the arteries shall have dilated to their maximum, the remainder must enter the capillaries with the same velocity

cæteris paribus, as that which moves in the aorta; the sum of the areas of the extreme branches however, is greater than that of the aorta; hence the blood will circulate slower in them than in the aorta, and this coincides with the 51st. experiment of Spallanzani.— I consider the blood as an almost inelastic fluid, and what little is required to compensate for its compression, is scarcely worth naming; the principal reason, why the blood does not cease to flow in an open artery, is because of the elasticity or contractility of the artery; this being stretched to its maximum point, by the first portion of the blood, it follows, that the remainder must obey the same laws, that a liquid would in ascending a metallic pipe, or in other words, that through two cylinders of equal diameters, in any part of the body it will pass with the same velocity.—

Upon the known principle of hydrostatics, that a liquid will not pass beyond an angle in the same calibre, with the same velocity with which it first moved, it has been thought that the arteries should possess dilatations to correspond with

each turn: and accordingly, I have seen the arch of the aorta exhibited as a case in point: Struck with the idea, at the time I heard it, I have since revolved it in my mind, and the conclusions arrived at, are deduced from the following considerations;

In an open tube, the sides of course, being permanently fixed the first jet of liquid, will necessarily be retarded in passing an angle: but let this tube be completely filled with it, and then, force applied at one end; the liquid being inelastic, and incompressible, will start from the opposite end, with precisely the same motion, as where the force is applied, because each globule transmits the motion unchanged: it is immaterial to a perfect sphere whether it act laterally, the power being behind, or straight forward, when surrounded by fulcra as is a globule thus situated, friction being an attribute unkown to atoms. Hence, there is no obstruction in passing an angle under such circumstances: but we know the arteries to be moveable tubes, and attended with curves instead of angles: moreover, they are never empty: hence in the systole of the heart, (the aorta having previously closed

in a slight degree upon its contents, from the contractility of texture; the first jet of blood, dilates it to the point, beyond which it cannot go, and then the force & velocity are simultaneous throughout. — Considering the column as a whole, undoubtedly, some of its momentum is spent in the effort to straighten the arteries, but this occurs only in the commencement of the systole, and before the tube is fixed by having attained its extreme point of dilatation. Admitting these considerations to be correct we have no need of these dilatations, beyond each curve, inasmuch as the fluid will pass as well, nay, better, without them. If the blood move, as I have stated, the want of dilatations can have no influence on its velocity, and inasmuch as the surface of the artery is extended, it will have a tendency to rupture, exactly on the principle of a hydrostatic bellows. If the artery be dilated to twice its natural size without a proportionable increase of thickness, there will be at least 4 times the pressure, originally sustained; thus, did these alledged dilatations exist, and without an increase of parietes, the pressure must be increased with the sur-

face, and of course the tendency to rupture. Even were the arteries complete bony canals, possessing no mobility, the unbrokenness of the sanguineous column, & its non-elastic property, would subject it to the same laws: the liquid moves simultaneously in all its parts, when confined to a regular cylinder. — It is very true that the aorta possesses, especially in old subjects, a considerable dilatation at its great curve; but if the preparations I have examined, are to be relied on, this dilatation does not correspond with what it ought to exhibit, were its object as stated in the preceding theory. In an angular tube, the increased circumference should be just beyond the bend, because the impediment exists at its extreme boundary, and until the liquid has reached that impediment it loses but little of its momentum. This however does not hold in the aorta, for the dilatation exists immediately in its curve, and is lost even before that curve is completed. How then can this dilatation facilitate the passage of the blood? that it does, is evident, or it would not exist. Look at the innominata, the

the left carotid, and subclavian arising from its upper portion: is it not designed for the easier transmission of the blood into those vessels? This is the use I would assign to it, and I think the only object it can be calculated to fulfil.

If the position I have attempted to disprove be true, certainly these dilatations should exist in the carotid artery, which makes no less than six great curves before it gets into the cranium: yet I have never seen a plate or preparation, in which this dilata- was rendered evident. I will however render the position I have assumed more firm and conclusive, by a reference to the experiments of Spallanzani: In the 21st. exp^t., he proves that in the pulmonary artery, the motion of the blood "was uniformly the same, whatever might be the angle, formed by these vessels." Experiment 61st. "The blood circulated with its usual velocity in an intestinal vein, although it had 25 curvatures." These experiments furnish collateral evidence to shew the non existence of dilatations, otherwise the blood could not have flowed with usual velocity. —

I therefore think the position, which Bichat so stren-

uously urges, viz. that the blood has a simultaneous movement throughout the vessels, amply proved, not only by his own, but Spallanzani's experiments, and as a consequence, the curves or angles of the artery, have no effect, in diminishing the circulatory force; also: That the elastic tissue of the arteries, contracting by its own inherent & vital or, it may be, mechanical properties, upon each diastole of the heart, must necessarily be again restored to their maximum point of dilatation, by the first motion of the systole, this dilatation taking place simultaneously throughout: the maximum point of dilatation, is that point, when the circular fibres of the middle tunic, are brought to their stretch: or, in other words, as a succession of cords upon an elastic tube will limit its dilatation, so these circular fibres act upon the artery. Bichat observes that "the circular fibres diminish, as we approach the branches of the arterial tree". thereby proving their use in the structure to be contrary to the opinion generally received.—

As regards the pulsation of the arteries, Bichat I think has settled the point, that they pulsate by their locomotion

or more properly their attempt to straighten: and here, by the way, is another strong argument, in favour of his position, above stated, that the column at one end moves, as at the other, for if it did not, this universal and simultaneous, effort to become straight would not take place: the artery would have an undulation corresponding to the force, but not the motion of the heart, and we should feel the pulsation in the aorta before the extreme arteries. This however, is not the case: every pulsation of the heart is universally felt at the same moment throughout the system. Hence, the blood, driven into the capillaries, and against the curvatures, lengthens the series of tubes and forms the pulse: but the structure of the artery, has every thing to do, with this motion: it is elastic, firm & thick, & transmits the impression of the pulsation, to some distance. Were the parietes of the veins the subjects of this motion, we should scarcely feel the transmission of its force. This Bichat proved by joining together, an artery and a vein, and making the blood of the former, circulate through the latter: nothing could be felt in the vein, but a kind of

rustling, whilst the artery pulsates as usual. The best illustration we can have of the arteries in situ, is afforded by the leaden pipe of a hydrant, which may run uncovered in a tortuous direction. Here, if the stream be permitted to flow, & then suddenly stopped by means of the cock, (which will answer to the blow given the column by the heart), we perceive a quick locomotive effort, corresponding exactly to the pulsation of the arteries. It is on this principle that the pulsation of the heart against the ribs can be accounted for, & on no other, so satisfactorily.

Having passed the set of tubes denominated the arteries, the blood next enters the capillary system: and, at this stage we have no lack of discordant opinions: the mechanicians looked upon this congeries of vessels, as passive in the circulation: an opinion by no means the least plausible, formerly existed, & has been revived in France, that the dilatations of the right heart assisted materially by the vacuum it formed. Whatever value we may attach to the argument in its favour, it cannot explain the various phenomena

of the capillary circulation: There are facts occurring continually to the observing eye, which I think cannot be elucidated, without giving the capillaries the power of motion. The afflux of blood following every irritation, the phenomena of inflammation &c. &c. - will I think be difficult to explain on other grounds. If the capillaries be a set of passive tubes, in what manner, are absorption, nutrition secretion, & calorification accomplished, for all these functions are seated in the capillaries. To explain the multitudinous operations of the living system, and the mysterious changes and alterations unceasingly taking place in the human body, without allowing an agency to the capillaries, is I think, beyond the ingenuity of man. It is in fact the system on which all the others are founded, and to which each function in the economy is subservient: it is the seat of almost all diseases, and without its groundwork, no rational explanation can be given of their pathology. What attention then should not be bestowed upon so important a part of the machine? Yet there are few parts of which so little is known,

and still less demonstrated. That mere mechanical laws will not solve the difficulties which encounter us here is evident; What theory that we possess, will on rational principles, and with admitted truths, explain to us, why the blood which until birth has passed from the pulmonary artery, into the ductus arteriosus, at that period ceases to flow in its former channel, although the avenue is still open, and the vis-a-tergo more than sufficient to propel blood into it? This, amongst many of a similar nature, will demonstrate the utter futility of solving every problem, in vital action, by mathematical theories.

It is the opinion of Bichat, that the blood has an oscillatory movement given it, in the capillaries; but such a motion appears very inadequate to the effect designed: When we consider the structure of the veins, and their valves, may we not attribute some of the capillary phenomena to a similar construction. I must confess, I am rather sceptical, on the alledged uses of the venous valves: that they have some other use besides supporting the column of blood merely, I think may be safely concluded; and if they extend to the capillaries

along with the venous fibres, I think some future day, will assign a more probable use than is generally attributed to them.

These latter, viz: the venous fibres, run in a longitudinal direction: I have already endeavoured to shew that the arterial, exert their influence in resisting the great lateral pressure of the blood, which is beyond all comparison greater than the vertical, inasmuch as the lateral surface is of much more extent, than that of the ends of the arteries: reasoning from analogy, we should suppose that the venous fibres resisted, the longitudinal stretching of the veins: this however cannot be since the force in that direction is very small: may they not then have some influence in the motion of the blood? It appears to me more probable, than the oscillatory movement of Bichat.

Dr. Jackson alledges, from microscopical observation, that the minute or extreme circulation is not performed in vessels: unless we consider, the whole frame, as a series of convoluted vessels, we cannot, without this fact before us, believe in the omnipresence of the fluids: and with it the pathology of disease is intelligible and rational: yet it is certain that the

venous capillaries must have a commencement, which he thinks is in cul de sacs. This however, though doubtless correct, is but the commencing link: and without a cause of motion to the venous blood, the chain of explanation is far from being complete: whether it be from capillary attraction, oscillatory movement, muscular contraction, or some other power is yet to be determined. But the rapid March of Science, and the fresh discoveries continually breaking in upon her clouds of Error and Ignorance, lead me to hope, that this with many other unravelled intricacies, will, ere long be plucked from among the arcana of Nature, and added to the well earned laurels of Medicine.—